QSO-Expert for WINDOWS
Quarry Scheduling Optimisation
Using Artificial Intelligence Techniques

1. OBJECTIVES

QSO-Expert represents the most recent innovation in deposit evaluation, mining simulation and production planning. The two main objectives of applying QSO-Expert are:

♦ secure a steady supply of raw materials from the quarry to the clinker production units

♦ economic utilisation of the raw material sources, in most cases this means at minimum cost and maximum lifetime.

By means of improved planning, the problem of waste minimisation can be better dealt with, and capacity of mining equipment and their constant load level can be better optimised, as can mining and transport logistics, etc. – to mention only the most important factors.

2. THE METHODS BEHIND QSO-EXPERT

It is important to realise that QSO-Expert is not only concerned with the chemical raw mix requirements. Mining technical and logistical questions can likewise be considered, or may even be the prime objective.

This is due to a novel approach, the combination of conventional numerical optimisation methods with symbolic and heuristic techniques of Artificial Intelligence. A powerful user interface under the WINDOWS environment facilitates easy computation and evaluation of various planning tasks. The results can be interpreted "at a glance", thanks to compact graphical visualisation.

Besides the comprehensive graphical capabilities, the essential innovation is the previously mentioned combination of numerical and heuristic methods.

Computation of solutions, which are chemically optimal and technically feasible with as little user interaction as possible, can be a tedious task, when only numerical methods are employed. Theoretically speaking, there are purely numerical solutions, however, computationally intractable on the PC of today. Hence, to solve the problem - computation of chemically optimal and technically feasible plans - in an elegant way, heuristics ("experiences and rules") must be conceived.

Utilising a heuristic approach potential mining areas are selected (i.e. taken into consideration for mining) and evaluated by means of numerics. The best solution is accepted. Based on it "the next solution is computed" etc. In practice, this represents individual stages of mining progress, the quarry schedule.

Without going into further technical detail: The solutions achieved represent the chemical optimum, whilst mining technical feasibility is warranted. The activity of a human expert is emulated, and in many respects even exceeded. For example in:

♦ simultaneous consideration of several chemical variables

♦ special evaluation of mining areas

♦ quick computation of technically feasible plans

♦ reproducibility of results and appropriate reasoning.

It should be stressed, that it is not an uncontrolled, fully automatic quarry scheduling that is desired, but an efficient support of the human expert. Tedious, repetitive routine is eliminated, complex chemical and special relations are understood correctly and managed easily.

3. QSO-EXPERT IN PRACTICE

In particular, QSO-Expert offers the following possibilities.

1) Block Model content: all chemical variables and block states are displayed in form of coloured block maps in an impressive and clearly arranged manner.

2) Geological (in-place) reserves can be calculated quickly in all detail for the total deposit or parts of it.

3) Computation of reserves in terms of raw mix, under consideration of eventual correctives:

   - without mining technical restrictions (chemically optimal)

   - with mining technical restrictions (chemically and technically feasible) and the option to permit waste, if necessary.

4) Development of medium to long-term mining plans.

5) Using blast hole dust analysis data or other continuous production data, short-term production planning on a daily to weekly basis can be achieved. The build-up of batch type or continuous preblending beds can be planned and controlled.

3.1 Graphical User Interface

QSO-Expert is a software package according to the WINDOWS standard. Fig. 1 to 4 show the user interface and provide some additional detail to QSO-Expert in practice (see above).

What are the main differences between QSO-Expert (from 1989) and QSO-Expert for Windows (from 1995)?

Some new features and benefits are:

- simplified programme handling; fully mouse driven

- compatibility with WINDOWS environment (e.g. direct printing on a large variety of plotters)

- better waste handling (optimisation of waste treatment; maintaining constant stripping ratios)

- widely improved block model display (blockmaps to scale; cross-sections; perspective views; display of world co-ordinates and topographical features)

- quick on-line help (context sensitive help utility)

- block models of up to 16'000 blocks can be dealt with, better control of quarry scheduling due to additional advanced mining rules.

QSO-Expert represents the latest state-of-the-art by its combination of Artificial Intelligence with Linear Programming, utilising the advantages of both methods.

4. EXPLANATION OF FIGURES 1 TO 4

Figure 1:
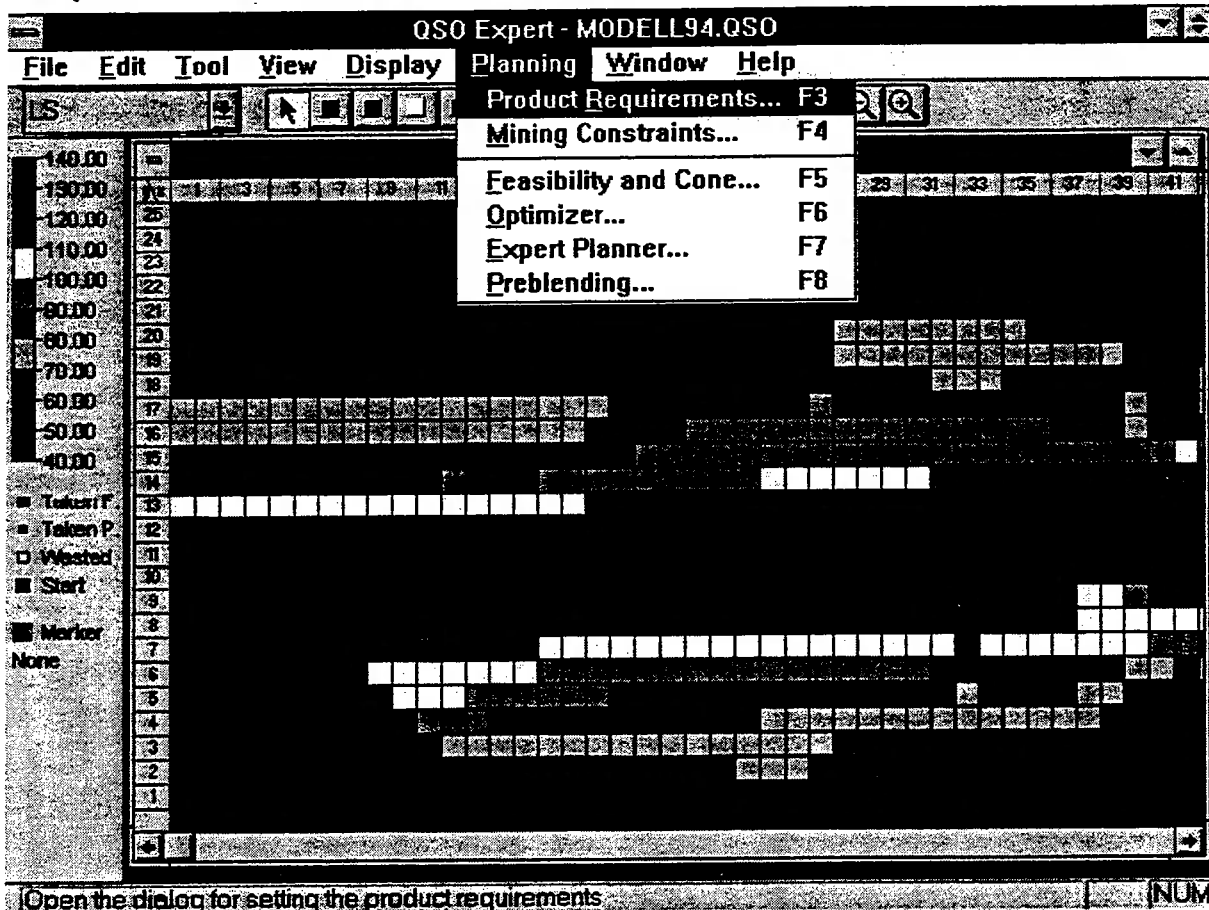
A certain level of the deposit is represented as a coloured block map. Each square symbolises in this case a block of 60 x 60 x 10 m3. The colours display the lime saturation. Reddish and yellowish colours represent high grades, greenish and bluish ones low grades. Any variable which is contained in the block model can be shown. Thus, the deposit inventory is displayed in an impressive and easily understandable way.

The "Planning" menu is opened and allows the selection of various activities such as: definition of product (raw mix) requirements, specification of mining rules and constraints, checking mining feasibility, computing optimal deposit utilisation strategies, planning actual quarry schedules and doing short-term production scheduling by building-up a pre-blending bed.

**Figure 2:   The Deposit in Perspective View**
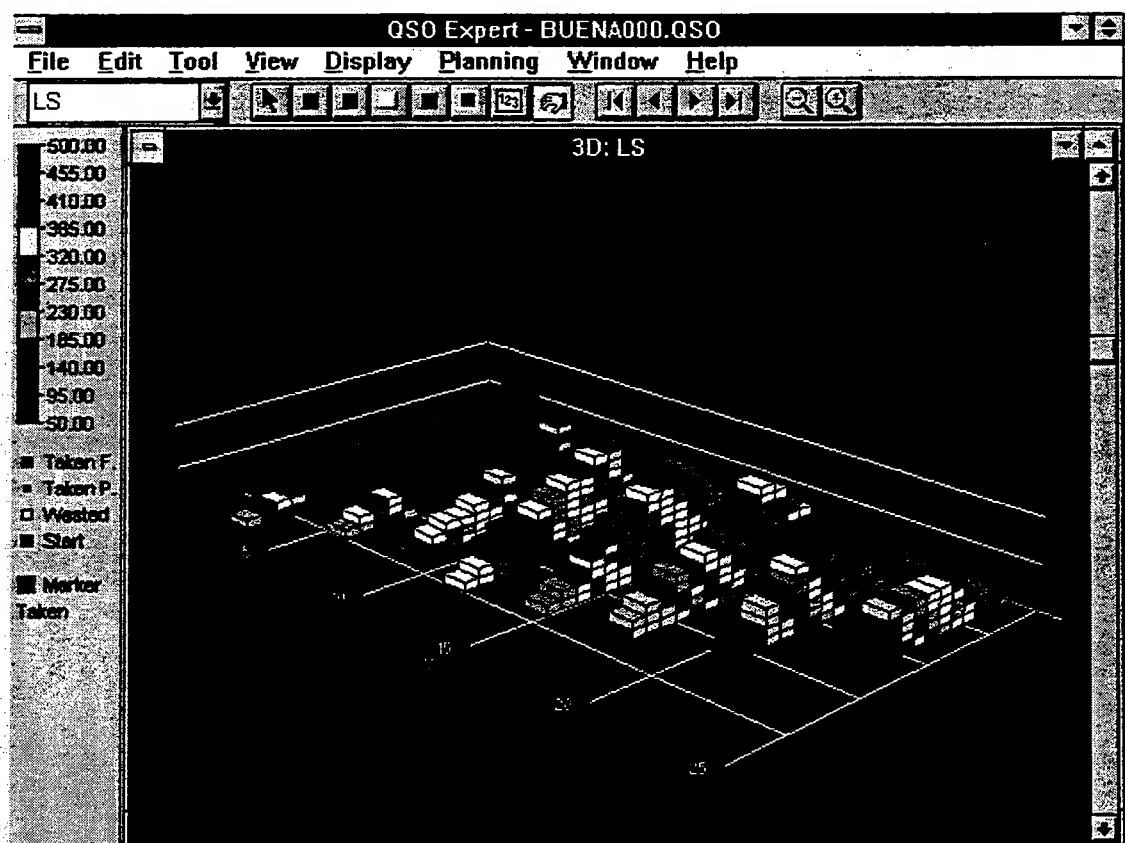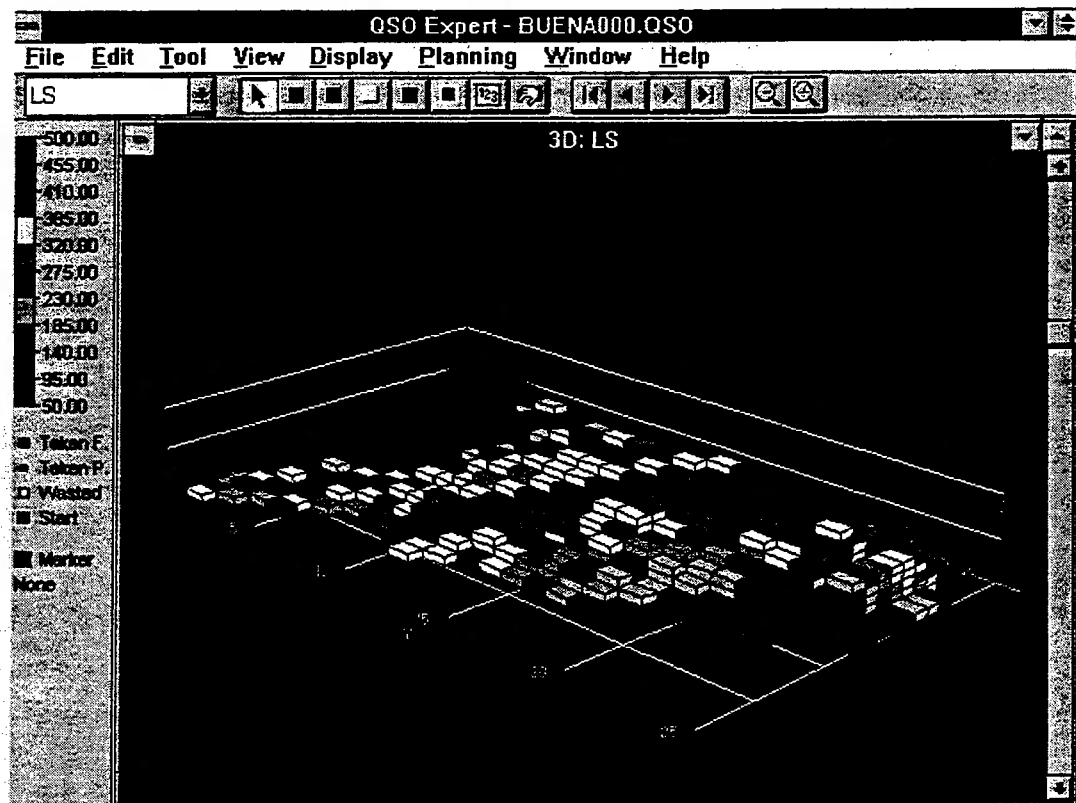
Spectators view the deposit from a specified viewpoint. They see the distribution of LS not only on the surface, but also along the cross sections. A very attractive way to provide insight into often complex deposit conditions.

Figure 3: **Results of a Scheduling Run**
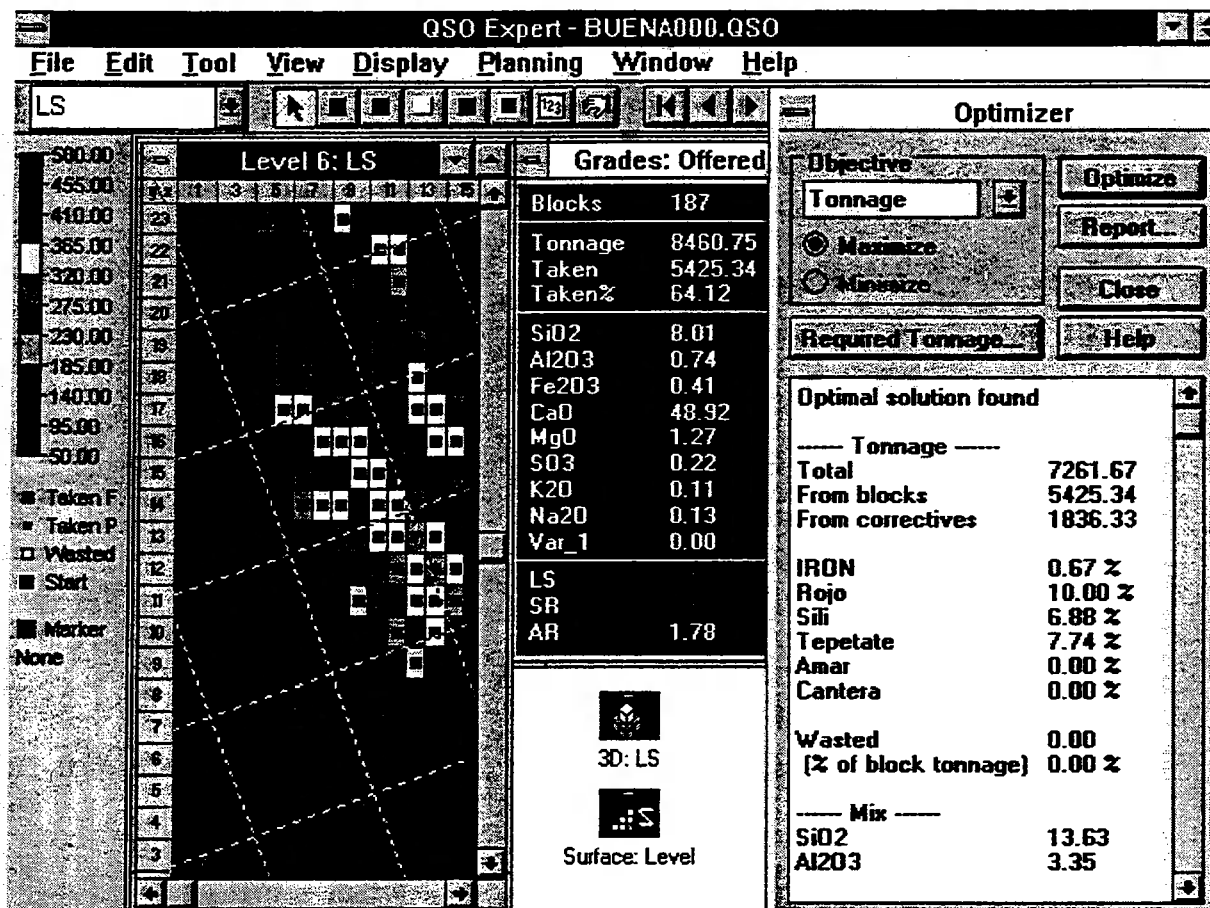
This figure shows the results of a scheduling run. The window "mix offered" describes the geological reserves on level 6 (left window). The right window "optimiser" describes chemistry and maximum quantity of the raw mix achieved. Quantities of the required correctives (clay, iron-ore and sand, etc.) are reported as well. The dotted blocks (left window) are the blocks which have to be mined to achieve the reported raw mix.

Figure 4: **Short-term Planning**
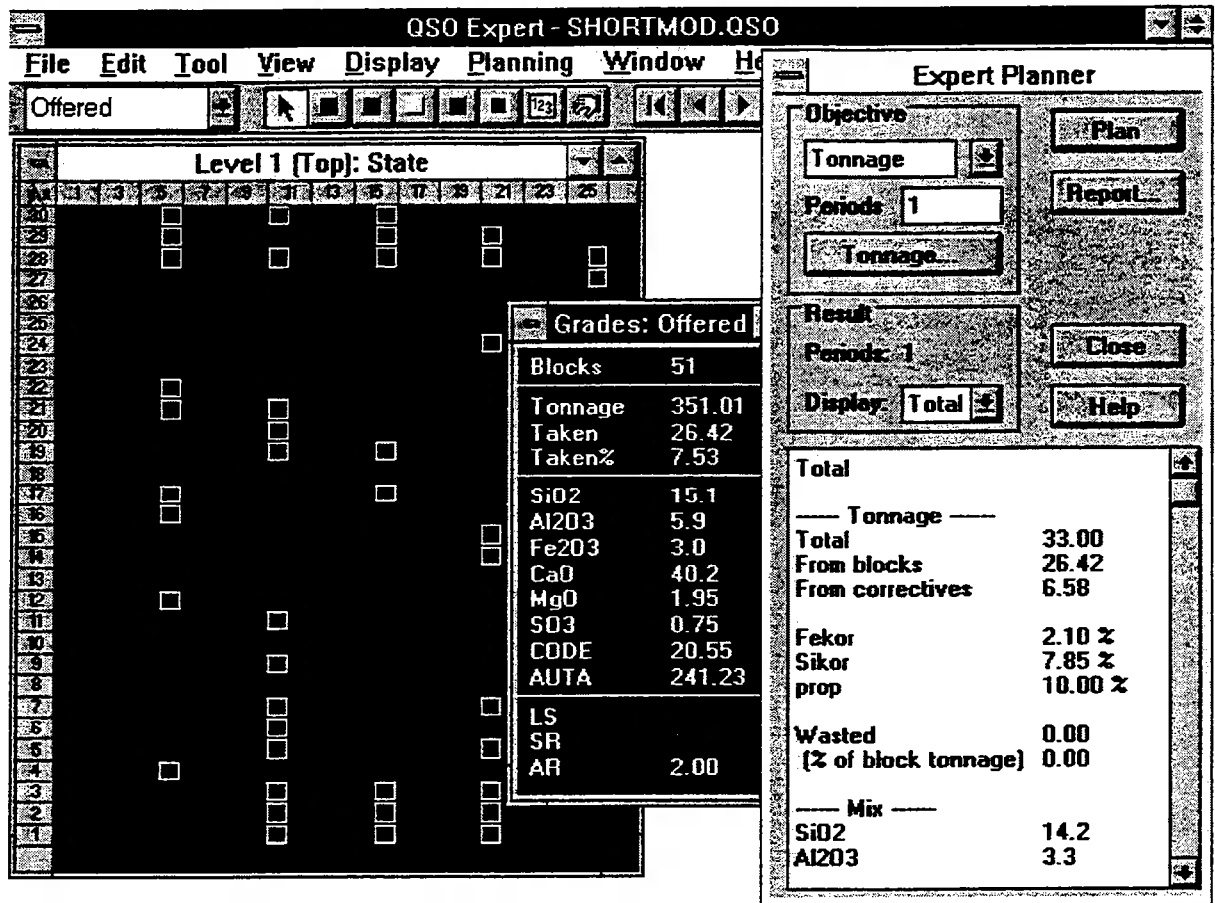
Each column in the left window represents a mining face, each red block represents blasted material, known in quality and quantity. There are 50 blasts with 355'000 tons of material (window "mix offered"). The four blocks marked with a black dot plus some correctives result in 33'000 t of raw mix in the desired quality, corresponding to the capacity of one preblending bed.

5. HARDWARE REQUIREMENTS

QSO-Expert runs on PCs with Intel 386 or 486 processors (with arithmetic coprocessor), 4 MB RAM, colour display (VGA) and an A4 colour plotter. Operating system is MS-WINDOWS 3.1 or higher.